

# Test Beam data analysis with CIVETTA

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BES III Italia - Frascati - 07/04/22

## Online monitoring during acquisition

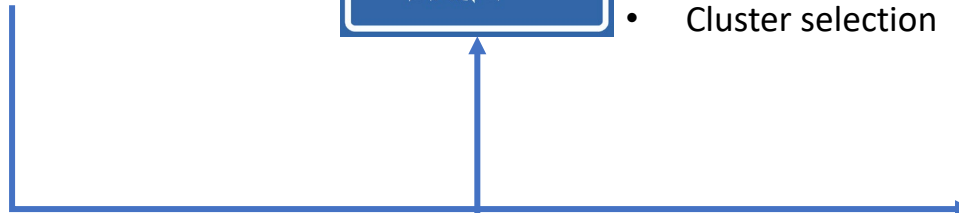
GUFI



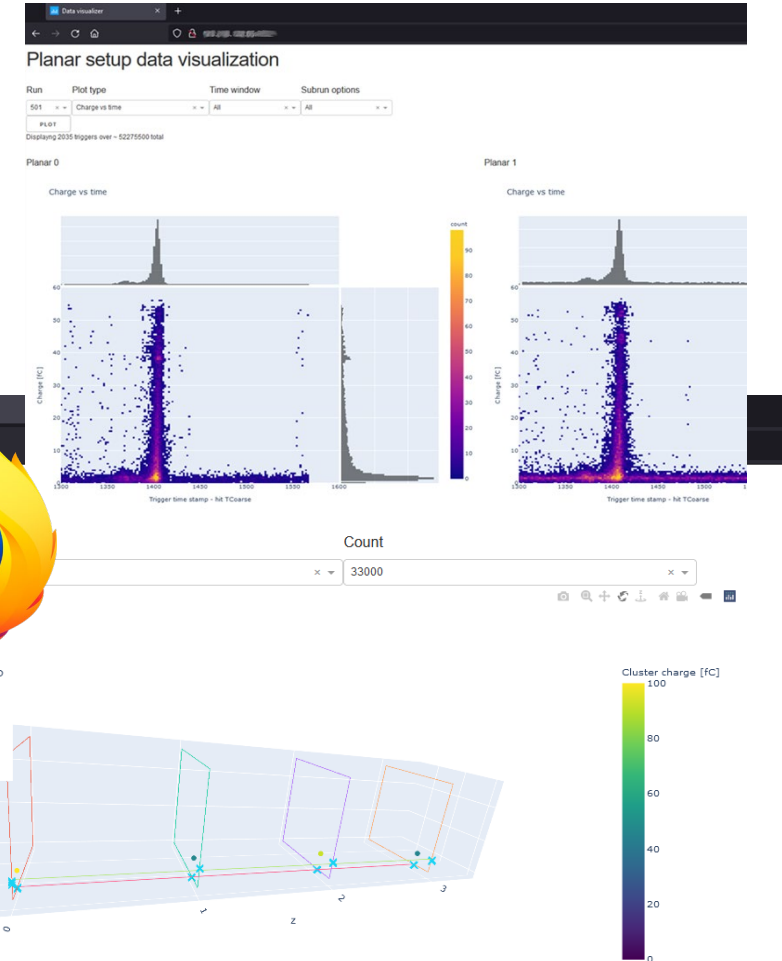
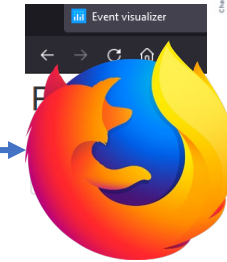
CIVETTA



- Data sampling
- Decode
- Calibration and mapping
- Clusterization
- Track fitting
- Cluster selection



GUFI  
ON



## Performance evaluation offline



- Full statistics
- Alignment on each run



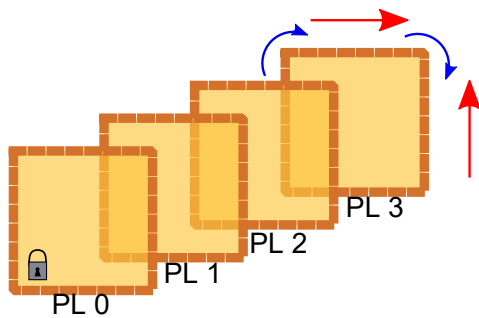
Event visualization

Efficiency

Resolution

High parallelism → ~30 minutes to analyze a full run (1M triggers). Thanks to Marco Destefanis for the computing resources

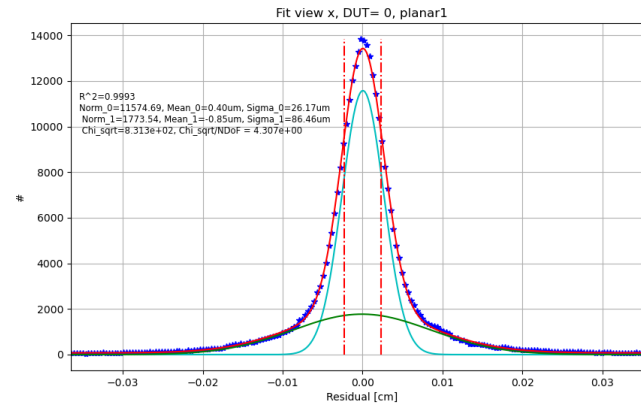
## Shift and angular alignment



$$\Delta x = ky + c_x$$
$$\Delta y = kx + c_y$$

## On the trackers (3 out of 4 detectors)

Track selection using  $\chi^2$  on residual distribution



## On the detector under test

- Alignment performed using the reconstructed position on the other view
- Efficiency calculation
- Noise contribution calculation

Example:

X: 0.9716 +/- 0.0009

Prob noise eff = 7.337E-03 +/- 2.882E-06

Real eff = 0.9714 +/- 0.0009

---

Y: 0.9663 +/- 0.0010

Prob noise eff = 4.977E-03 +/- 3.356E-06

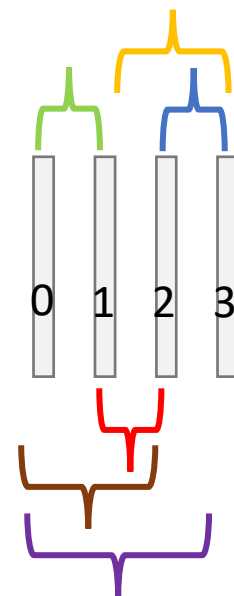
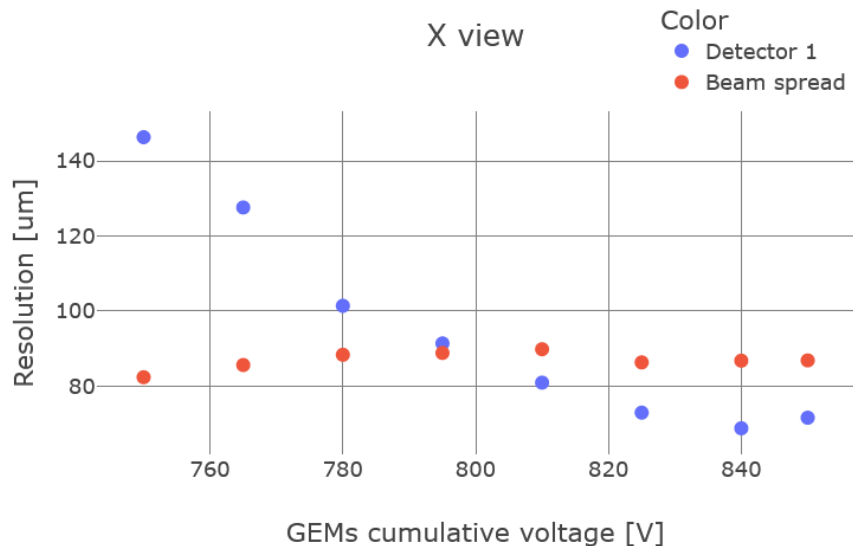
Real eff = 0.9662 +/- 0.0010

# Resolution

Taking into account the beam spread, the reconstructed position on each planar is compared with the one reconstructed by the others

Verified with:

- Toy Montecarlo
- $\sigma_{\theta} \sim 3\sigma_{\theta}$
- Beam spread doesn't change with HV scan:



Std dev of the distribution:  
positions measured by 0 – positions measured by 1

$$\sigma_{01} = \sqrt{\sigma_0^2 + \sigma_1^2 + \sigma_{\theta}^2}$$

$$\sigma_{12} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_{\theta}^2}$$

$$\sigma_{23} = \sqrt{\sigma_2^2 + \sigma_3^2 + \sigma_{\theta}^2}$$

$$\sigma_{02} = \sqrt{\sigma_0^2 + \sigma_2^2 + (2\sigma_{\theta})^2}$$

$$\sigma_{13} = \sqrt{\sigma_1^2 + \sigma_3^2 + (2\sigma_{\theta})^2}$$

$$\sigma_{03} = \sqrt{\sigma_0^2 + \sigma_3^2 + \sigma_{\theta}^2}$$

$$\sigma_{\theta} \sim 3\sigma_{\theta}$$

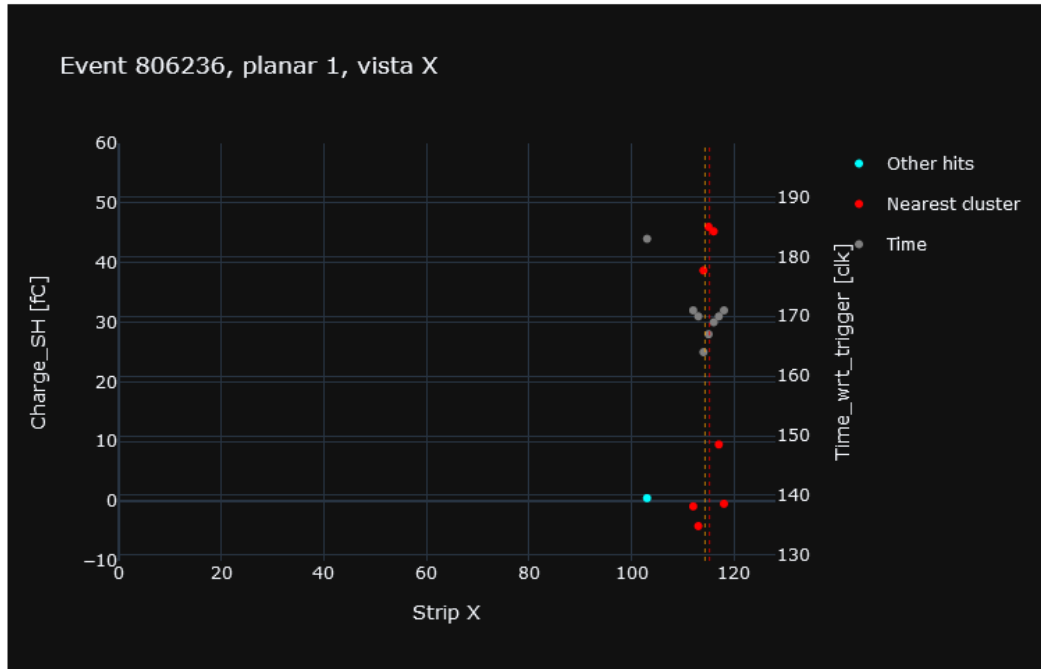
Similar to:

*Performance studies of resistive-strip bulk micromegas detectors in view of the ATLAS New Small Wheel upgrade*  
T. Alexopoulos

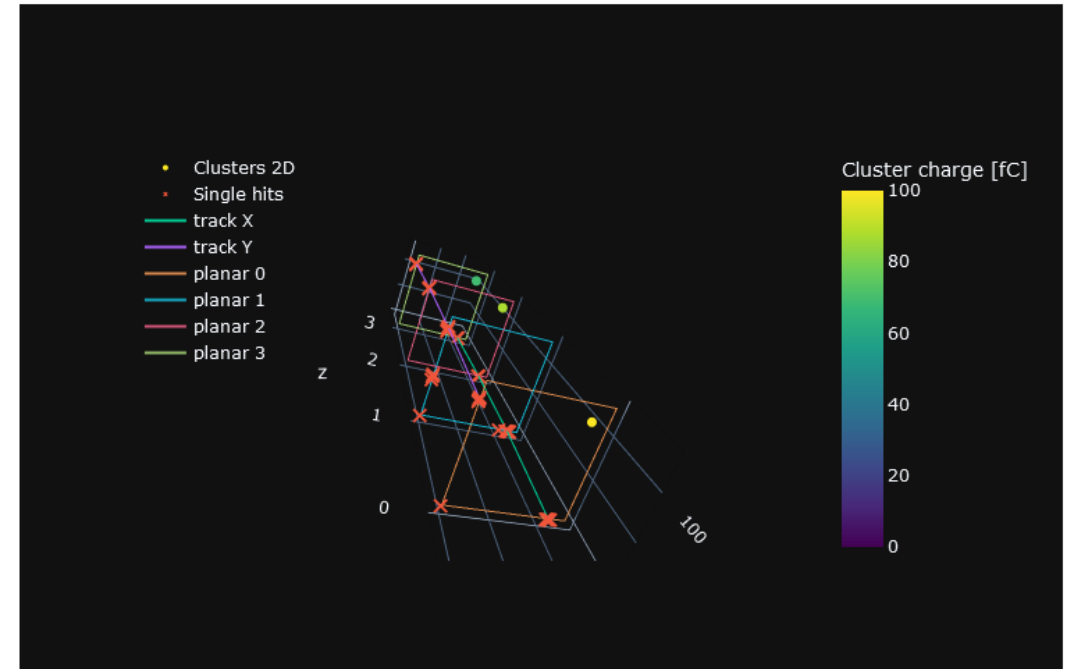
*Example:*

- $\sigma_0 = 92 \mu\text{m}$
- $\sigma_1 = 81 \mu\text{m}$
- $\sigma_2 = 78 \mu\text{m}$
- $\sigma_3 = 77 \mu\text{m}$
- $\sigma_{\theta} = 90 \mu\text{m}$
- $\sigma_{\theta} = 267 \mu\text{m}$

# Event visualization



1D, single view, charge and time

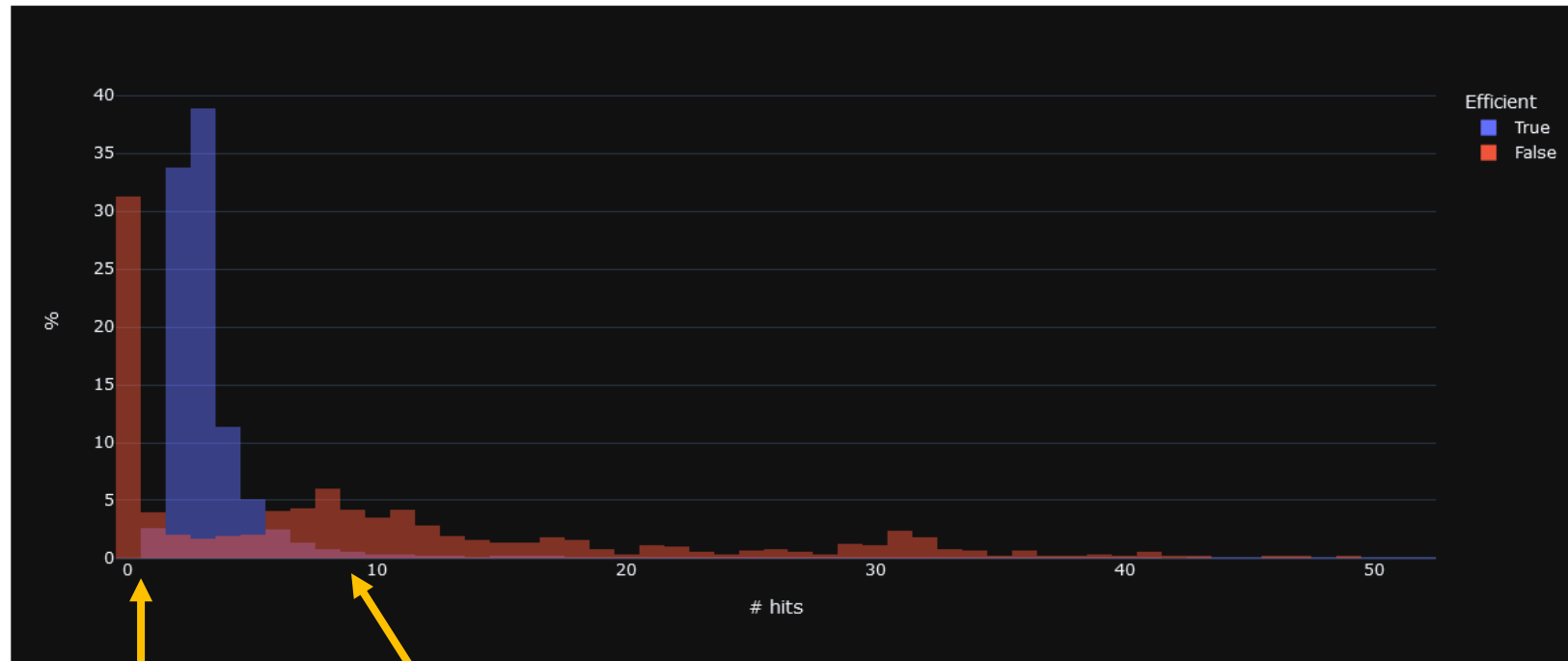


3D, full system

Useful to study non efficient events

# Non efficient events

Two kind of non efficient events



Not enough hits

Too many hits

Example run:  
4.7 % events non efficient on X view

# Non efficient events: too many hits

## Two kinds of events:

### Delta ray (many hits, high charge):

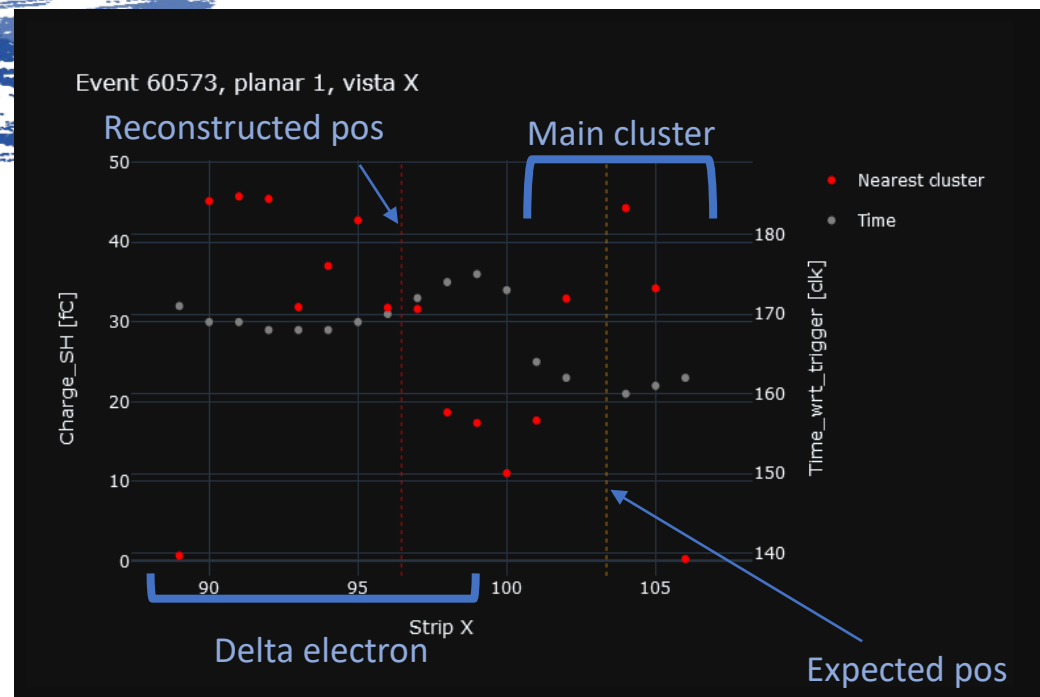
Intrinsic detector phenomenon

Main cluster can be reconstructed with advanced analysis method

Example run:

~38 % event non efficient on X view

~1.8 % of total events



### Noise spikes (many hits, low charge):

Fluctuation on the common levels causes many channels on the same TIGER to fire

I am working on:

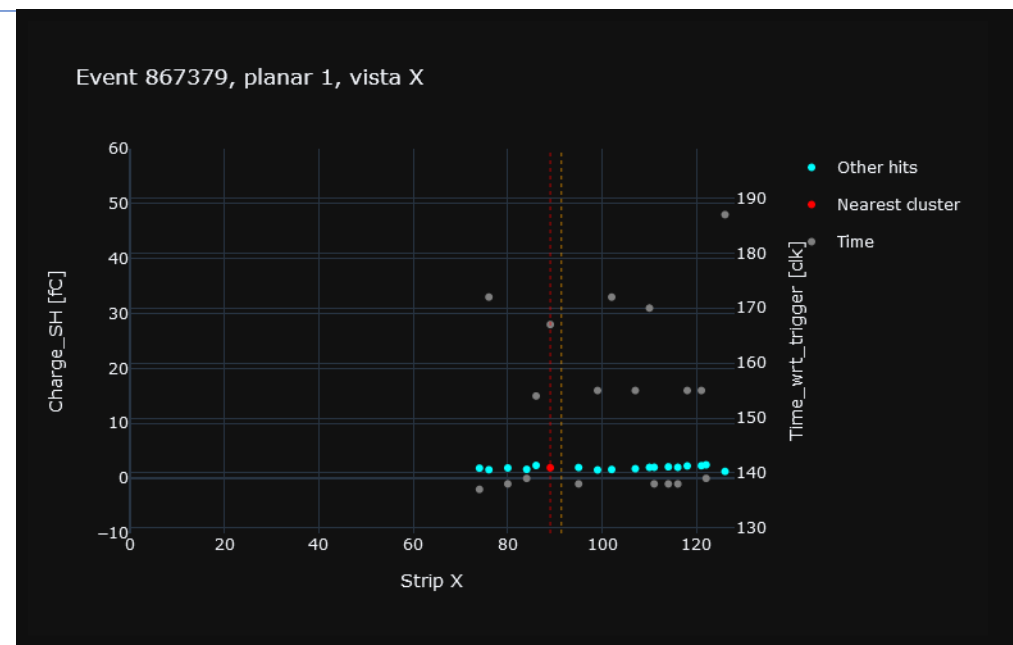
Use TIGER integrated Hysteresis on the discriminators to filter the noise keeping the same threshold

Expand the GEMROC buffering capabilities

Search for similar noise sources on the CGEM-IT

Example run:

~22 % event non efficient on X view





# Non efficient events: too few hits

Two kind of events:

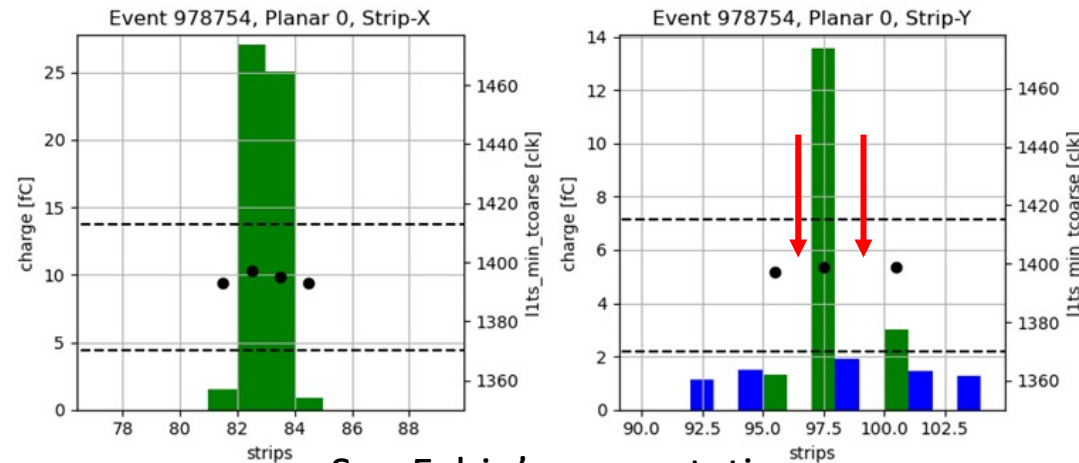
## Empty events

Probably due to a previous noise peak

Example run:  
~21 % of non efficient events

Firmware solution under test

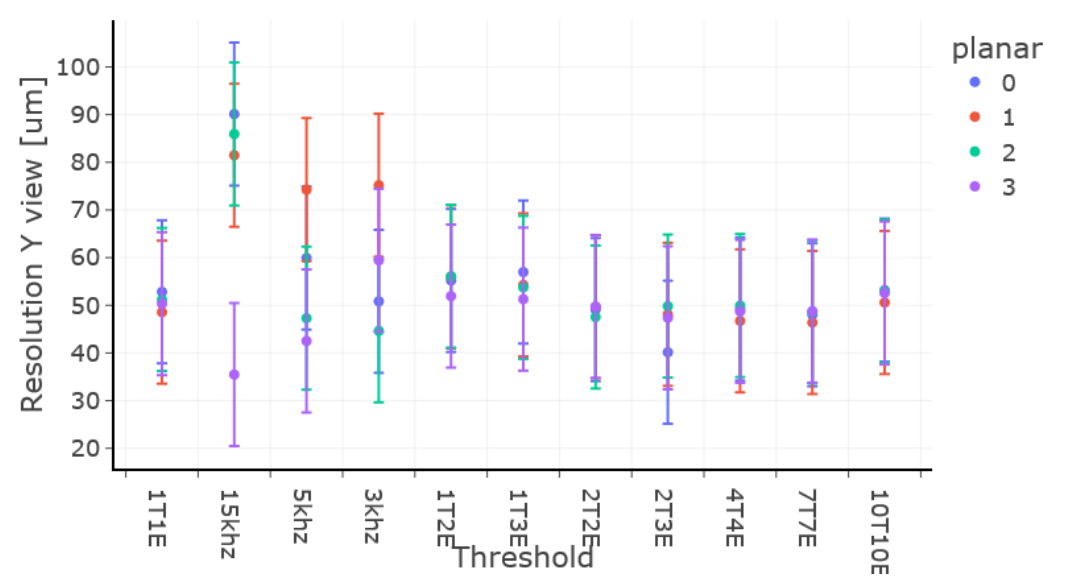
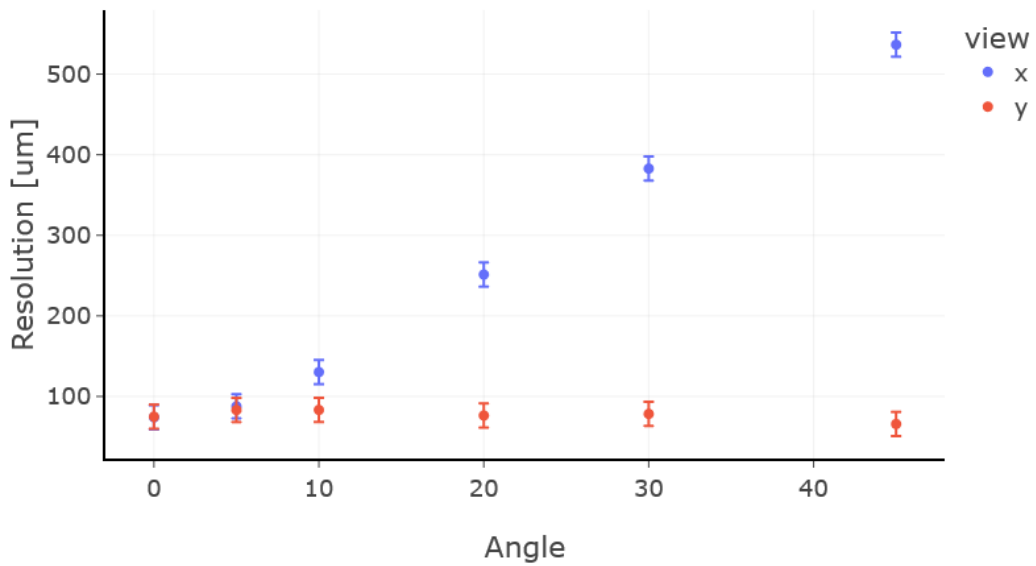
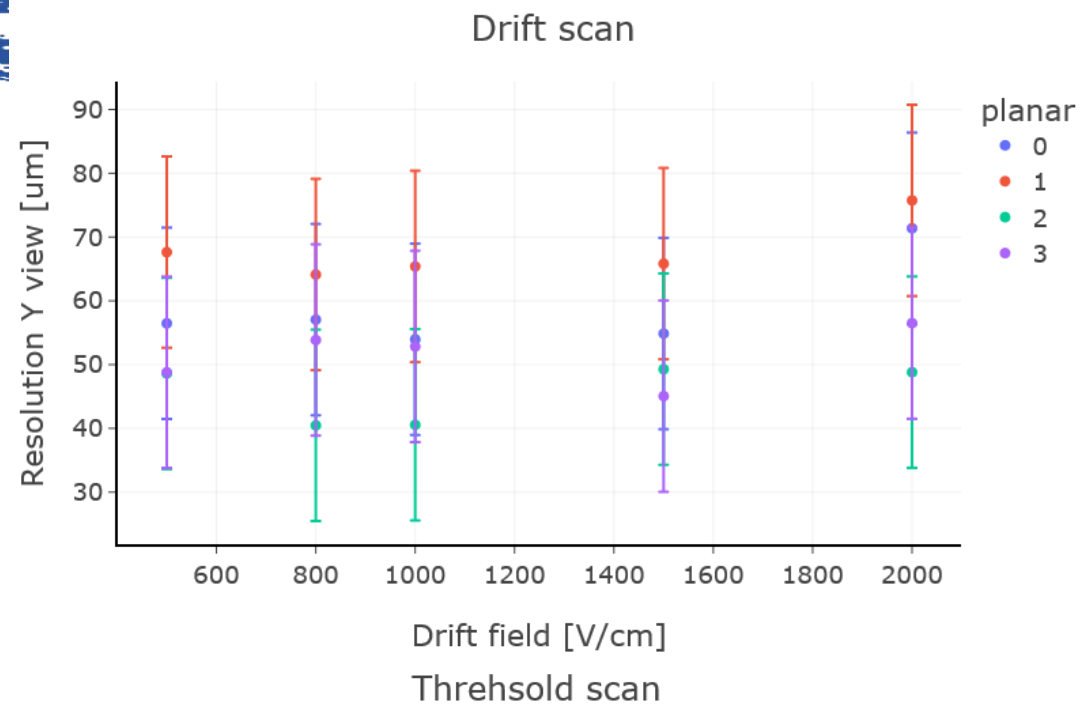
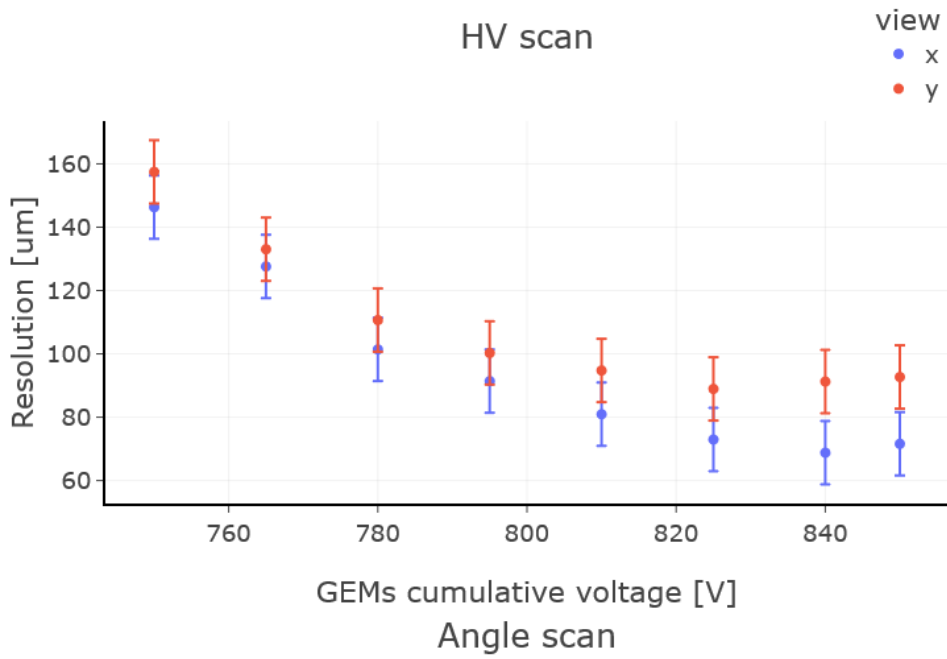
## Single missing hits



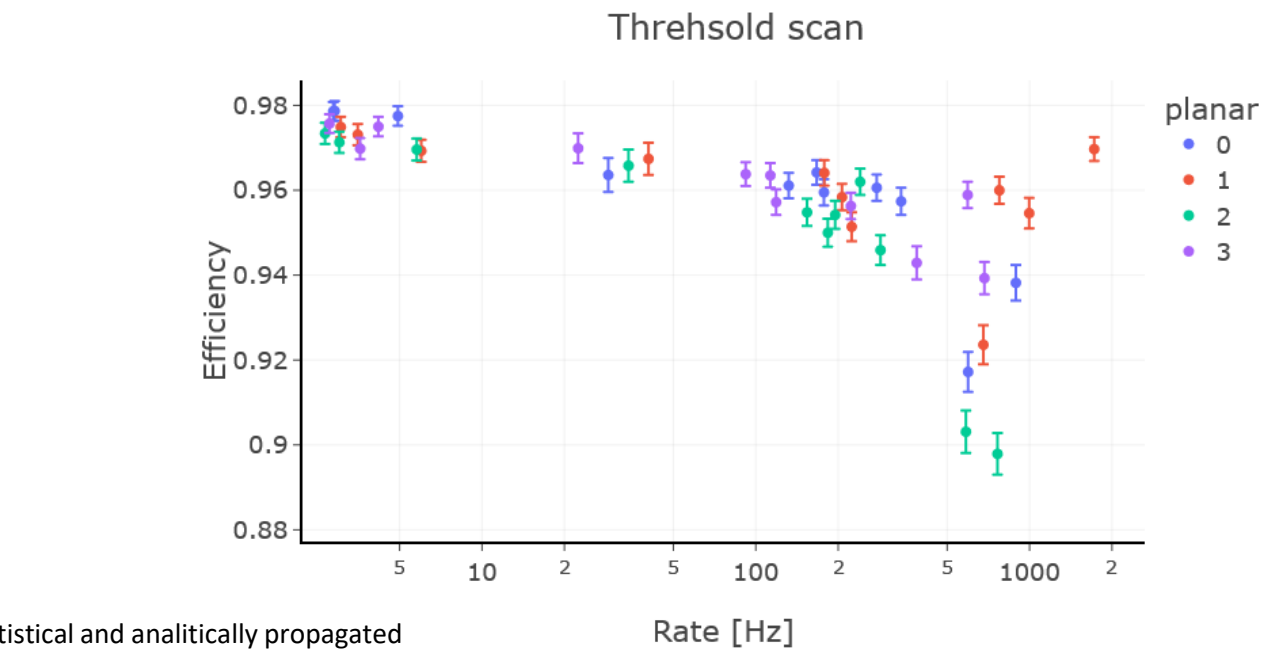
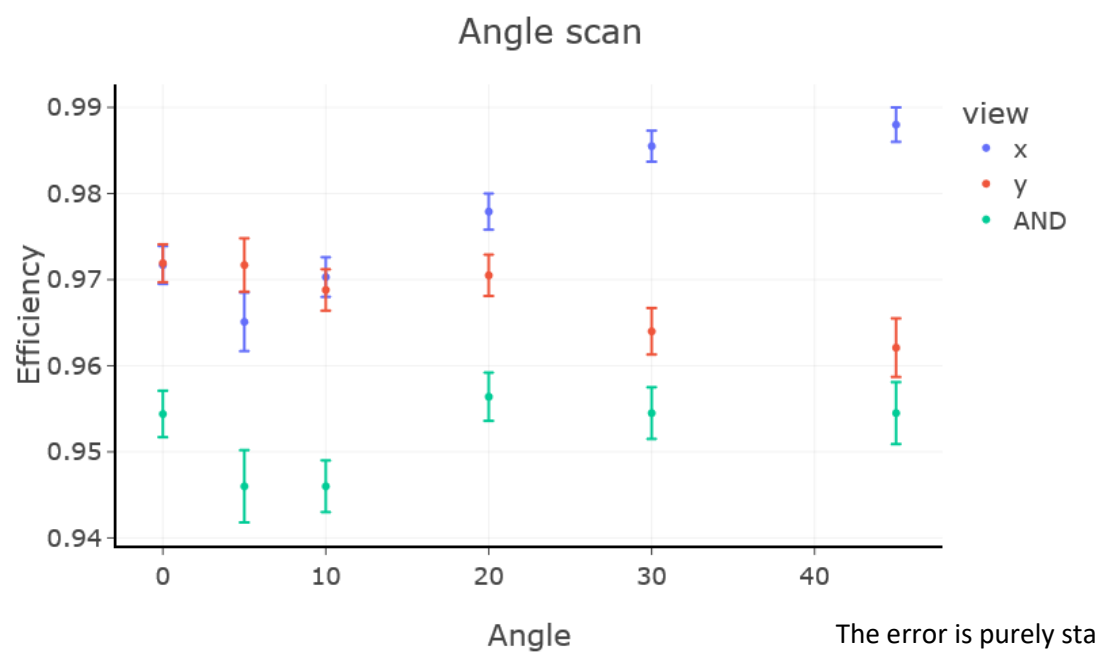
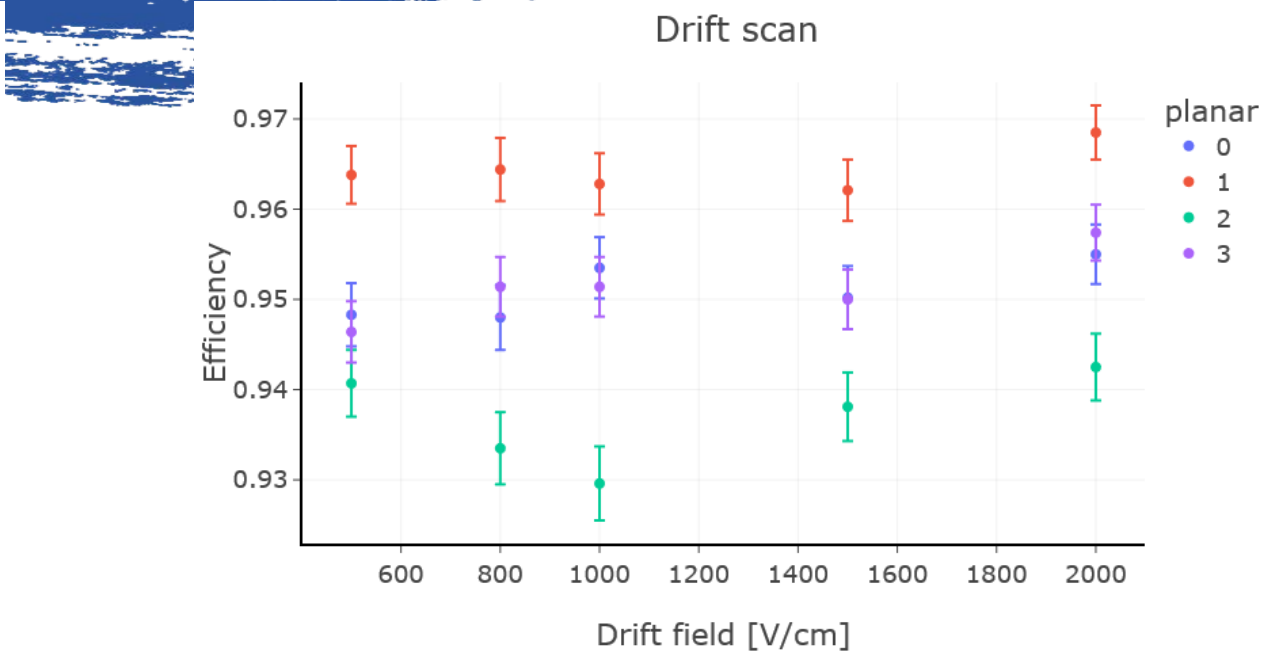
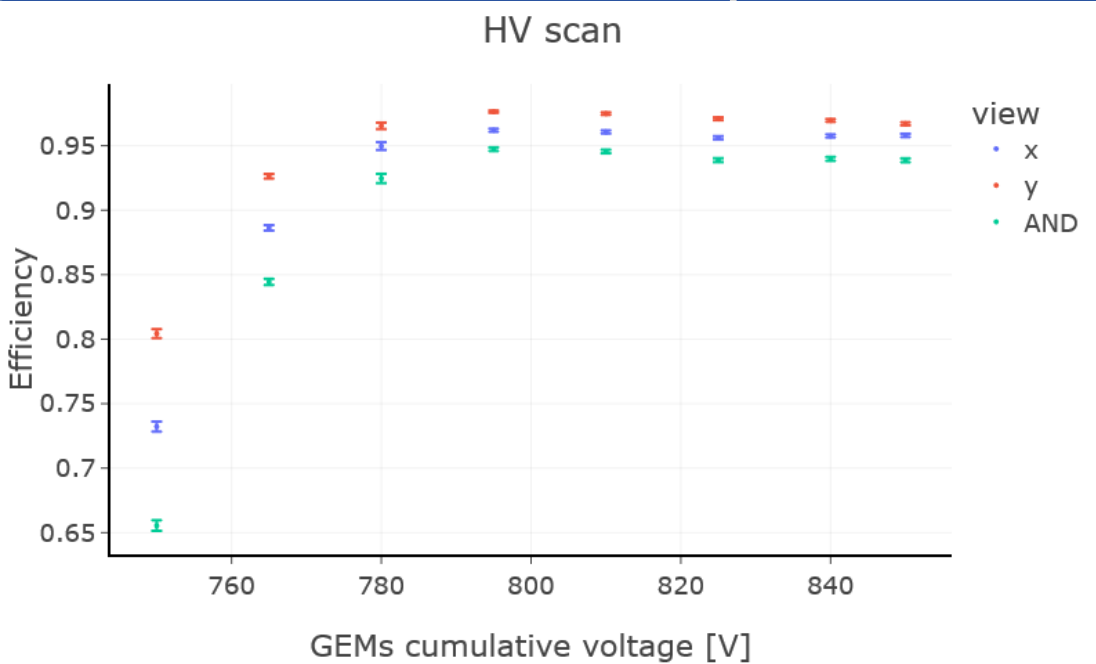
See Fabio's presentation

# Some results - resolution

The error is estimated at 15  $\mu\text{m}$  from the dispersion of the beam spread measure (preliminary)



# Some results - efficiency



The error is purely statistical and analitically propagated

- CIVETTA can now be used to evaluate the performance using test beam data
- The resolution is within the range of expected values
- The non efficient events have been investigated and I am already working on some solutions

A thick, horizontal blue brushstroke graphic with a textured, painterly appearance, centered on a white background. The word "BACKUP" is written in white, uppercase, sans-serif font across the middle of the brushstroke.

BACKUP

# Procedura efficienza – elementi iniziali

Allineamento:

Calcolato in precedenza, nella forma  
 $\Delta x = ky + c$  e  $\Delta y = kx + c$  (S.R.  
corretto)

Cluster 1D:

Posizione calcolata col C.C., nel S.R.  
della planare

# Procedura efficienza – costruzione tracce

1 Planare sotto test

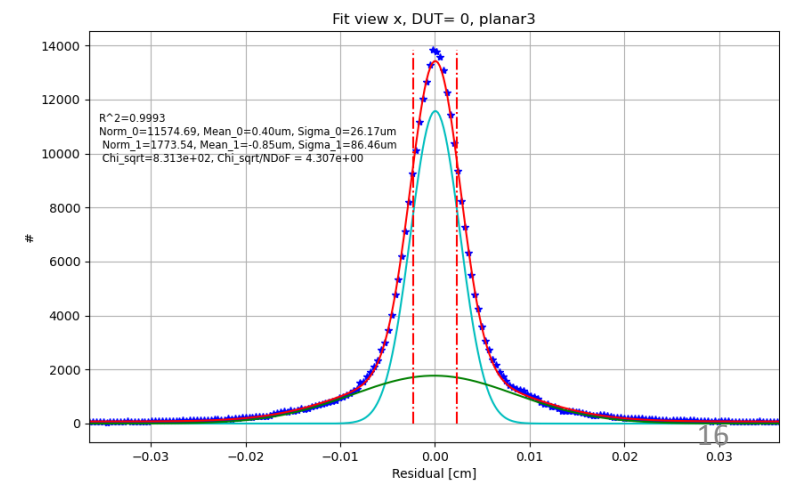
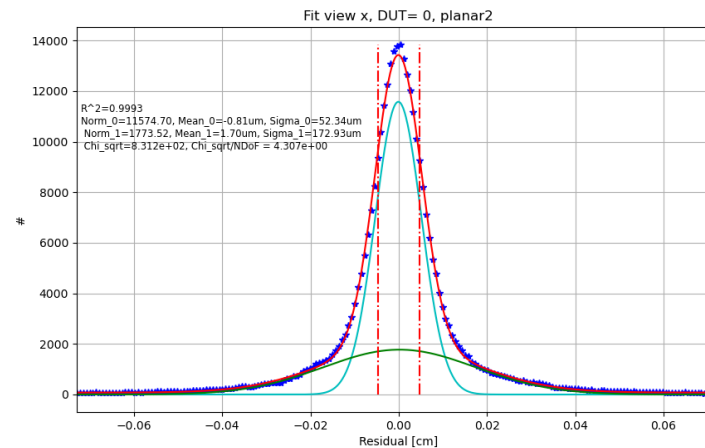
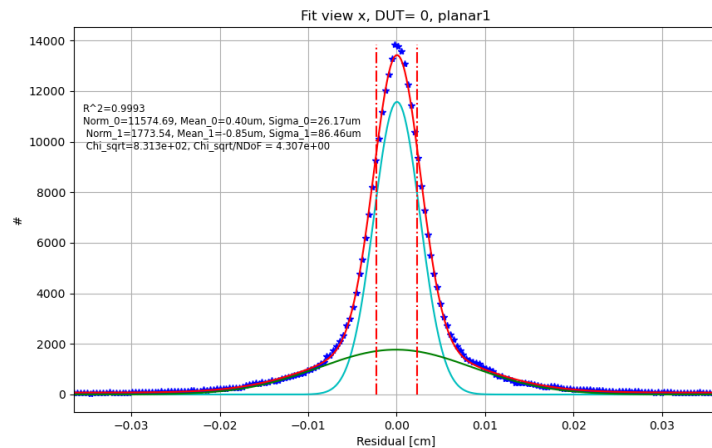
3 Planari per il tracciamento

## Procedura:

1. Per ogni tracciatore, viene selezionato il cluster più carico su ogni vista.
2. Vengono selezionati gli eventi con un cluster per ogni vista, per ogni planare (a questo punto posso anche escludere gli eventi multitraccia chiedendo un solo cluster per vista).
3. La posizione dei cluster su ogni vista viene corretta usando la posizione sull'altra vista
4. Fitto le tracce (3 punti)

# Procedura efficienza – selezione tracce (old)

1. Calcolo il residuo su ogni planare e lo fitto con la doppia gaussiana.
2. Calcolo la sigma come media pesata delle due sigma sugli integrali delle sigma delle due gaussiane
3. Selezione le tracce con tutti e 6 i residui (3 planari x 2 viste) entro 0.5 sigma
4. Questi eventi saranno quelli usati per i passi successivi (a.k.a. tracce buone)





## Procedura efficienza – selezione tracce new

1. Calcolo il residuo su ogni planare e lo fitto con la doppia gaussiana.
2. Calcolo la sigma come media pesata delle due sigma sugli integrali delle sigma delle due gaussiane
3. Per ogni traccia calcolo il chi quadro del fit come:

$$\chi^2 = \sum_{i=1}^6 \left( \frac{r_i}{\sigma_i} \right)^2$$

Con:

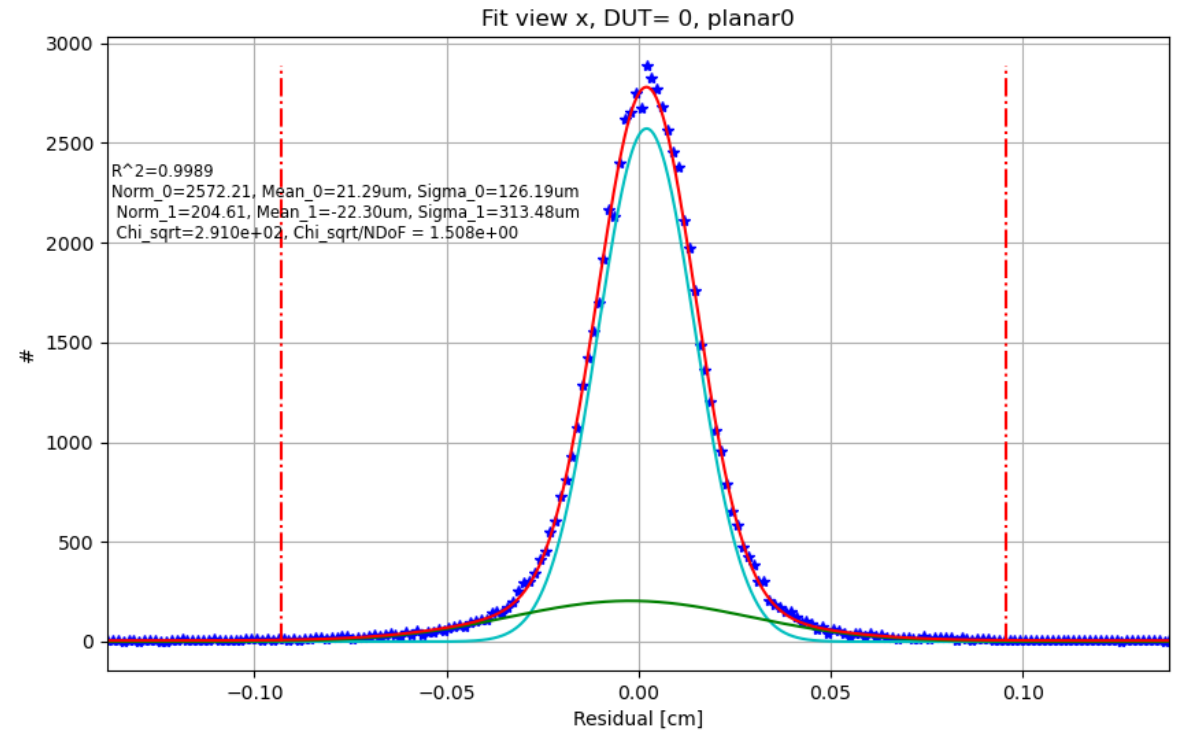
$r_i$  residuo (2 viste, 3 piani)

$\sigma_i$  sigma della distribuzione dei residui

4. Le tracce vengono tagliate a 20 sigma

# Procedura efficienza – intervallo di efficienza

1. Fra le tracce buone, prendo gli eventi a 4 punti 2D (corretti con allineamento)
2. Calcolo il residuo (non inclusivo) del punto sul piano di test e faccio il fit doppio-gaussiano
3. Calcolo la sigma come media pesata delle due sigma sugli integrali delle sigma delle due gaussiane
4. L'intervallo per essere considerato efficiente è preso come 6 sigma, la percentuale di integrale sottesa da questa selezione è segnata nel logfile.



# Procedura efficienza – verifica efficienza

Passando in rassegna gli eventi delle tracce buone:

1. Calcolo la posizione prevista sul piano sotto test
2. Prendo i cluster monodimensionali e applico la correzione usando la posizione prevista sull'altra vista
3. Se almeno un cluster è nell'intervallo di efficienza, l'evento è efficiente

$$\text{Efficienza misurata} \leftarrow E_m = \frac{k}{n}$$

Eventi efficienti

Tracce buone

$$\sigma_{E_m} = \sqrt{\frac{(k+1) * (k+2)}{(n+2) * (n+3)} - \frac{(k+1)^2}{(n+2)^2}}$$

<https://arxiv.org/pdf/physics/0701199v1.pdf>

<https://indico.cern.ch/event/66256/contributions/2071577/attachments/1017176/1447814/EfficiencyErrors.pdf>

Esempio:

-Eff dut 0:

X:0.9702 Y:0.9643

Efficiency in range [3.2,7.8]

X: 0.9733 +/- 0.0009

Y: 0.9660 +/- 0.0010

# Procedura efficienza – effetto del rumore

$$E_m = P_+$$

$P_+$  Probabilità positivo  
 $E_m$  Efficienza misurata

$$P_- = 1 - P_+ = (1 - P_N) \cdot (1 - P_E)$$

$$1 - P_+ = 1 - P_N - P_E + P_N P_E$$

$$P_+ = P_N + P_E - P_N P_E$$

$$P_E = \frac{P_+ - P_N}{1 - P_N}$$

$P_N$  Probabilità noise (falso positivo)  
 $P_-$  Probabilità negativo  
 $P_E$  Probabilità efficiente (positivo reale)

$$P_N = 1 - \overline{P_N}$$

$$\overline{P_N} = f(k; l)^n$$

$f(k; l)$   
 $n$

Poisson distr.  $k = 0$ ,  $l =$  rate noise  
 Numero di strip nell'intervallo di eff

$$n = \text{round}\left(\frac{t \cdot 2}{0.00650}\right)$$

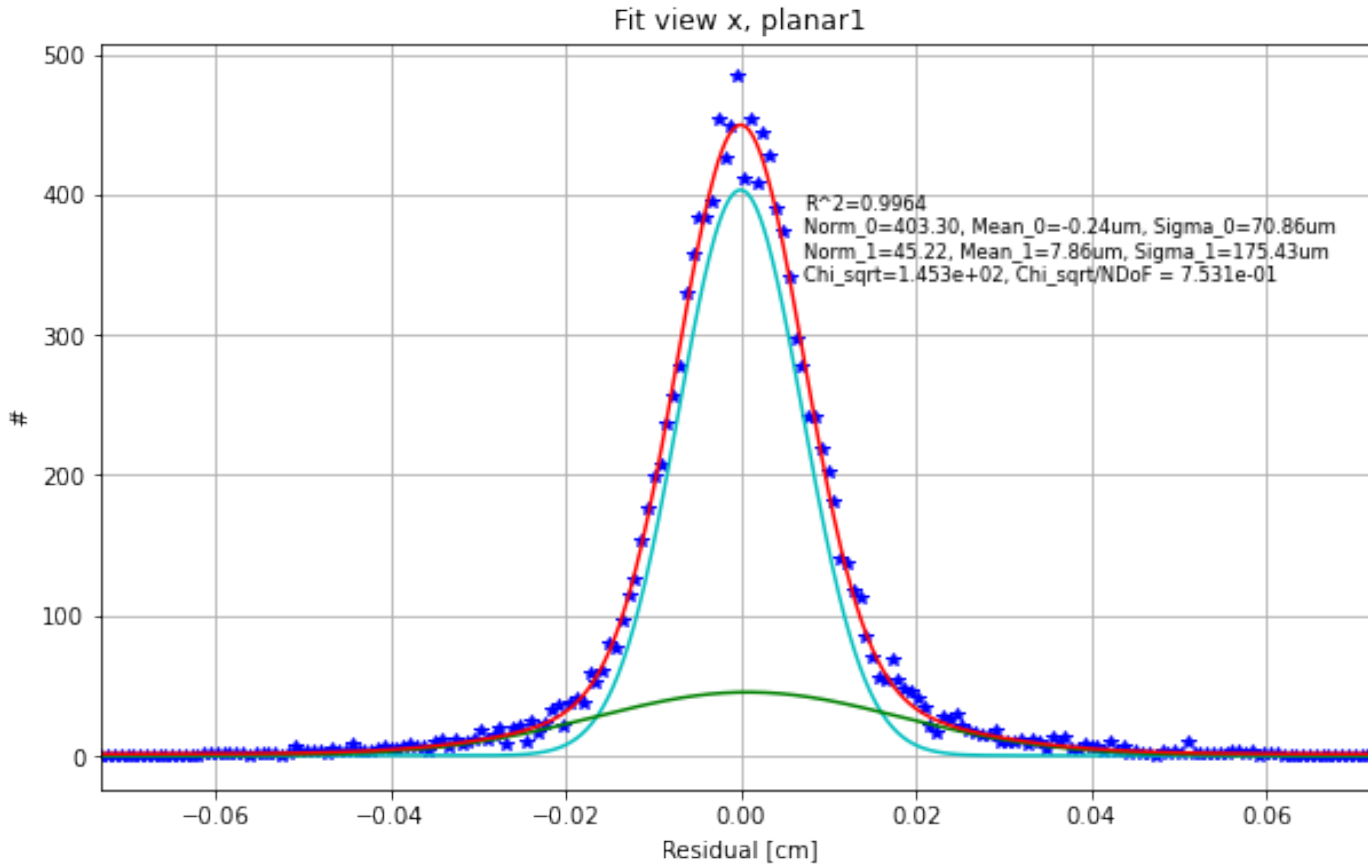
$t$

Intervallo tolleranza eff

Esempio  
 Planar 0  
 X: 0.9716 +/- 0.0009  
 Prob noise eff = 7.337E-03 +/- 2.882E-06  
 Real eff = 0.9714 +/- 0.0009  
 ---  
 Y: 0.9663 +/- 0.0010  
 Prob noise eff = 4.977E-03 +/- 3.356E-06  
 Real eff = 0.9662 +/- 0.0010  
 ---

# Risoluzione

# Procedura 1 – fit risoluzione



Usando i cluster confermati efficienti, fitto i residui con una doppia gaussiana.  
Come sottrarre il contributo del tracciamento?

# Procedura 1 – contributo tracciamento

## Procedura analitica

[SST Testbeam 2017 note on spatial resolution studies 2020-10-26.pdf](#)

1. Fittando le tracce, estraggo la matrice di covianza
2. Per ogni fit, calcolo l'errore sulla posizione ricostruita come a destra
3. Costruisco la distribuzione degli errori e ne estraggo la deviazione standard

$$U = a_U \cdot Z + b_U$$

$$\sigma_{DUT_U}^2 = \sigma_{b_U}^2 + Z^2 \sigma_{a_U}^2 + \sum_{i \neq j} Z \text{cov}(b_{U_i}, a_{U_j})$$

$U$  = coordinata (x o y)

$\sigma_{DUT_U}^2$  = errore sulla posizione ricostruita (U = x o y)

$\sigma_{b_U}^2, \sigma_{a_U}^2$  = errori parametri (diagonale cov)

$\text{cov}(b_{U_i}, a_{U_j})$  = altri elementi cov

## Procedura **Sukhonos**

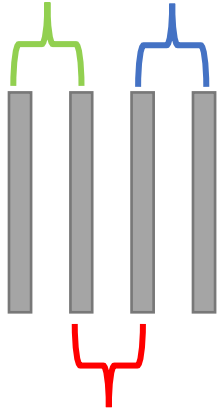
## Procedura 2 – ~~“Enemy”~~ Alexopoulos

The spatial resolution  $\sigma x$  is determined by comparing the positions reconstructed in two chambers of the same type. This method assumes that within the distance  $d$  between the two chambers the angular spread of the beam  $\sigma\theta$  is negligible with respect to  $\sigma x/d$ . For the typical case of  $d \sim 20$  cm and  $\sigma\theta \sim 100$   $\mu$ rad the contribution from the beam divergence to the micromegas spatial resolution amounts to  $\sim 20$   $\mu$ m, to be added in quadrature to the intrinsic spatial resolution of the detectors.

*Performance studies of resistive-strip bulk micromegas detectors in view of the ATLAS New Small Wheel upgrade  
T. Alexopoulos*



## Procedura 2 – Calcolo sulle planari vicine



$$\sigma_{01} = \sqrt{\sigma_0^2 + \sigma_1^2 + \sigma_\theta^2}$$

$$\sigma_{12} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_\theta^2}$$

$$\sigma_{23} = \sqrt{\sigma_2^2 + \sigma_3^2 + \sigma_\theta^2}$$

$\sigma_{ij}$

Sigma (from gauss fit) of the enemy distribution between planar i ad j

$\sigma_i$

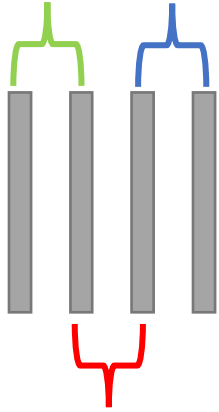
Risoluzione intrinseca planare i

$\sigma_\theta$

Contributo da beam spread in 10cm

3 equazioni, 4 incognite

## Procedura 2 – Calcolo sulle planari vicine Alexopoulos senza beam divergence



$$\sigma_{01} = \sqrt{\sigma_0^2 + \sigma_1^2 + \sigma_\theta^2}$$

$$\sigma_{12} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_\theta^2}$$

$$\sigma_{23} = \sqrt{\sigma_2^2 + \sigma_3^2 + \sigma_\theta^2}$$

$\sigma_{ij}$   
 $\sigma_i$   
 $\sigma_\theta$

Sigma (from gauss fit) of the enemy distribution between planar i ad j  
Risoluzione intrinseca planare i  
Contributo da beam spread in 10cm

Esempio assumendo  $\sigma_0 \sim \sigma_1$  e  $\sigma_\theta \ll \sigma_0$

$$\sigma_{01} = 152 \mu\text{m}$$

$$\sigma_{12} = 144 \mu\text{m}$$

$$\sigma_{23} = 142 \mu\text{m}$$

$$\sigma_0 = \frac{\sigma_{01}}{\sqrt{2}} = 107 \mu\text{m}$$

$$\sigma_1 = \frac{(\sigma_{01} + \sigma_{12})}{2\sqrt{2}} = 105 \mu\text{m}$$

$$\sigma_2 = \frac{(\sigma_{12} + \sigma_{23})}{2\sqrt{2}} = 101 \mu\text{m}$$

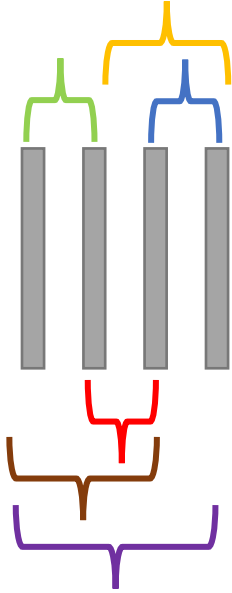
$$\sigma_3 = \frac{\sigma_{23}}{\sqrt{2}} = 100 \mu\text{m}$$

Ma  $\sigma_\theta \ll \sigma_0$ ?

<https://cds.cern.ch/record/2650989/files/PBC%20Report.pdf>

Dipende dai settings del fascio e dal materiale attraversato

## Procedura 2 – Aggiunta altre equazioni



$$\sigma_{01} = \sqrt{\sigma_0^2 + \sigma_1^2 + \sigma_\theta^2}$$

$$\sigma_{12} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_\theta^2}$$

$$\sigma_{23} = \sqrt{\sigma_2^2 + \sigma_3^2 + \sigma_\theta^2}$$

$$\sigma_{02} = \sqrt{\sigma_0^2 + \sigma_2^2 + (2\sigma_\theta)^2}$$

$$\sigma_{13} = \sqrt{\sigma_1^2 + \sigma_3^2 + (2\sigma_\theta)^2}$$

$$\sigma_{03} = \sqrt{\sigma_0^2 + \sigma_3^2 + \sigma_\theta^2}$$

Per verificare che:  
 $\sigma_\theta \sim 3\sigma_\theta$

6 equazioni, 6 variabili

# Procedura 2 – Esempio e verifica (1)

Soluzione del sistema [ $\mu\text{m}$  ]:

$$\sigma_0 = 92$$

$$\sigma_1 = 81$$

$$\sigma_2 = 78$$

$$\sigma_3 = 77$$

$$\sigma_\theta = 90$$

$$\sigma_\Theta = 267$$

Verifica 1:

$$\sigma_\Theta \sim 3\sigma_\theta$$

$$\sigma_\theta = 267$$

$$3\sigma_\theta = 270$$



# Procedura 2 – Esempio e verifica (2)

## Montecarlo

Ho fatto un piccolo Montecarlo in cui genero 20.000 tracce sui 4 piani. Vado poi a introdurre la risoluzione calcolata per i 4 detector, e guardo cosa succede ai residui di un'analisi simulata (3 tracciatori, 1 sotto test a rotazione). Risultati:

Sigma distribuzioni residui

Enemy senza beam divergence:

190  $\mu\text{m}$   
125  $\mu\text{m}$   
120  $\mu\text{m}$   
185  $\mu\text{m}$

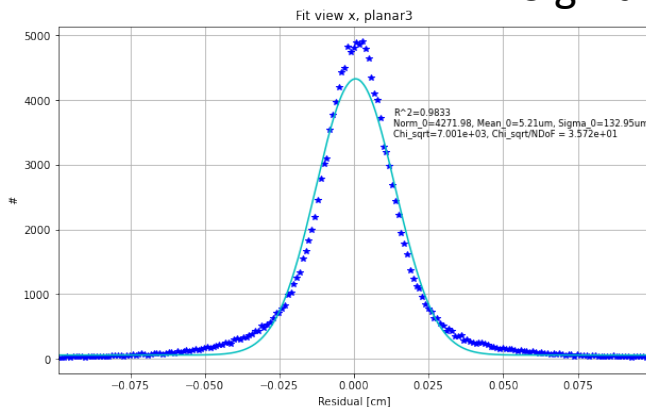
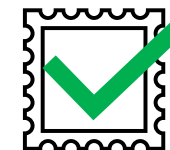
Sigma distribuzioni residui

Enemy con beam divergence:

154  $\mu\text{m}$   
99  $\mu\text{m}$   
94  $\mu\text{m}$   
147  $\mu\text{m}$

Sigma distribuzioni residui nei dati (fit singola gaussiana):

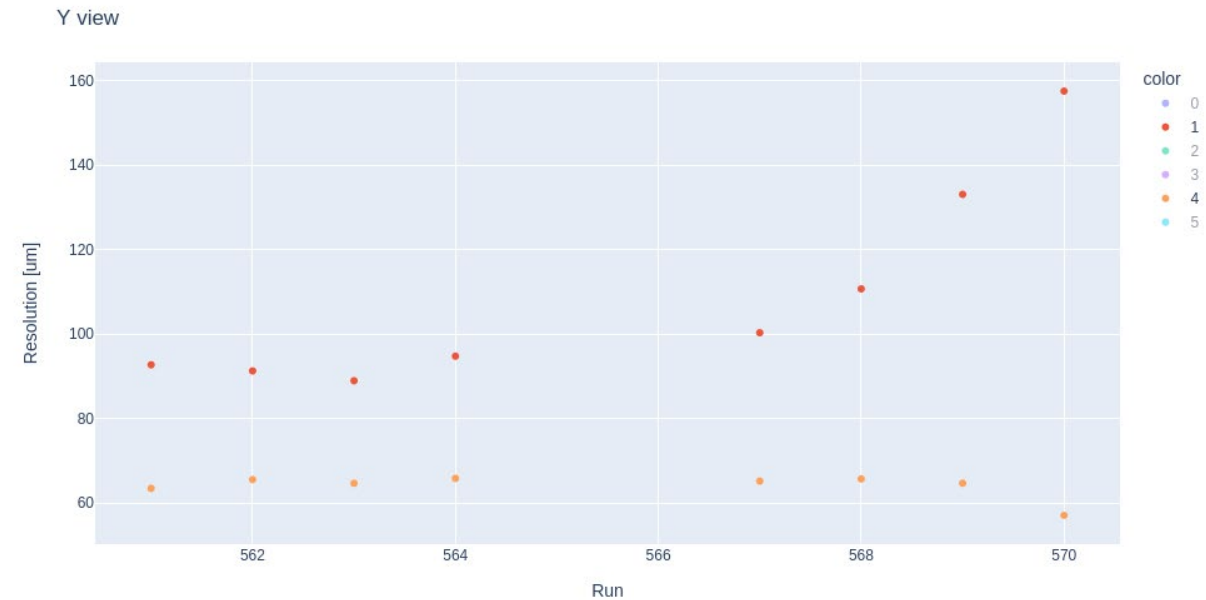
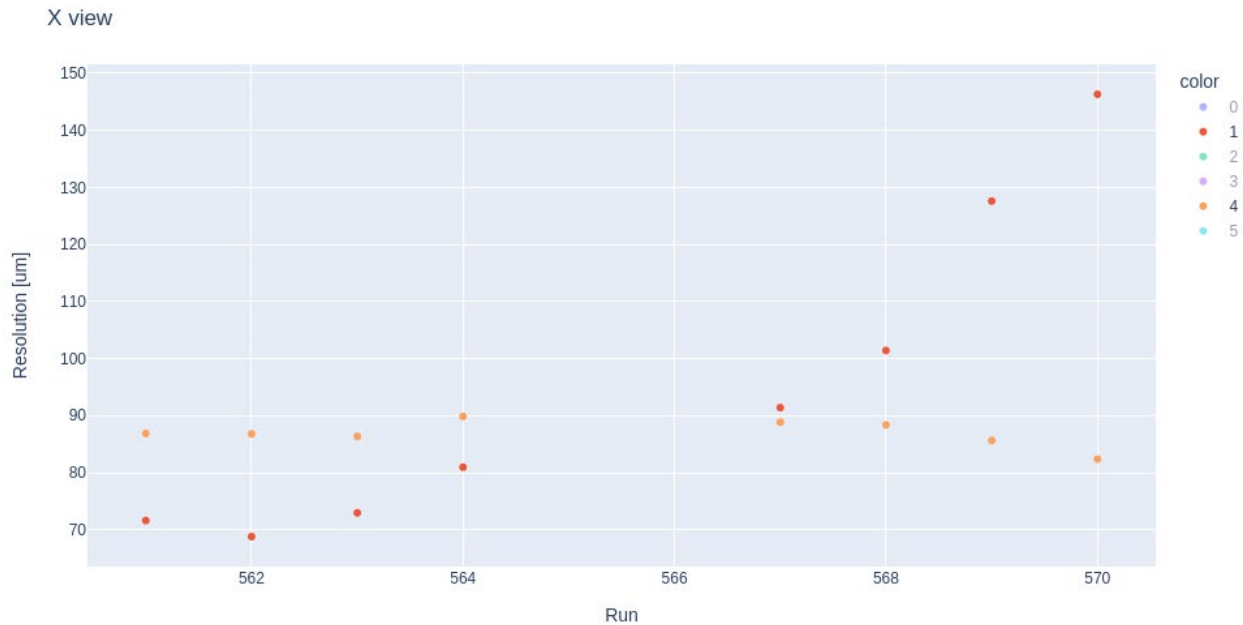
146  $\mu\text{m}$   
94  $\mu\text{m}$   
81  $\mu\text{m}$   
132  $\mu\text{m}$



# Procedura 2 – Esempio e verifica (3)

## Scan di HV

Prendendo i dati dello scan di HV, i valori di risoluzione cambiano, il valore di beam divergence rimane pressoché costante



rosso = planare 1, arancio =  $\sigma_\theta$

# Procedura Sukhonos

Planar 0 view x:  $\Sigma_0=112.07$  um,  $\Sigma_1=259.82$  um, error tracking: 95.67 um  
Planar 0 view y:  $\Sigma_0=109.32$  um,  $\Sigma_1=305.45$  um, error tracking: 95.92 um

Planar 1 view x:  $\Sigma_0=70.38$  um,  $\Sigma_1=158.98$  um, error tracking: 36.13 um  
Planar 1 view y:  $\Sigma_0=68.25$  um,  $\Sigma_1=191.18$  um, error tracking: 33.39 um

Planar 2 view x:  $\Sigma_0=64.14$  um,  $\Sigma_1=157.80$  um, error tracking: 41.10 um  
Planar 2 view y:  $\Sigma_0=62.09$  um,  $\Sigma_1=132.52$  um, error tracking: 52.63 um

Planar 3 view x:  $\Sigma_0=98.10$  um,  $\Sigma_1=250.02$  um, error tracking: 99.66 um  
Planar 3 view y:  $\Sigma_0=97.91$  um,  $\Sigma_1=232.22$  um, error tracking: 128.84 um

Sottraendo il contributo del tracciamento (anche tenendo conto della gaussiana più larga), vengono risoluzioni molto piccole o addirittura negative.

# Esempio risultati run 564

## Efficienza

```
---
Planar 0
X: 0.9732 +/- 0.0010
Prob noise eff = 9.259E-03 +/- 3.743E-06
Real eff = 0.9729 +/- 0.0010
---
Y: 0.9676 +/- 0.0010
Prob noise eff = 6.645E-03 +/- 4.194E-06
Real eff = 0.9674 +/- 0.0011
---
AND eff
AND: 0.9469 +/- 0.0013
Prob noise eff = 2.644E-05 +/- 2.995E-08
Real eff = 0.9469 +/- 0.0013
---
---
Planar 1
X: 0.9609 +/- 0.0012
Prob noise eff = 5.938E-03 +/- 3.963E-06
Real eff = 0.9607 +/- 0.0012
---
Y: 0.9755 +/- 0.0009
Prob noise eff = 2.415E-02 +/- 9.333E-06
Real eff = 0.9749 +/- 0.0010
---
AND eff
AND: 0.9455 +/- 0.0014
Prob noise eff = 7.181E-05 +/- 9.965E-08
Real eff = 0.9455 +/- 0.0014
---
---
Planar 2
X: 0.9551 +/- 0.0012
Prob noise eff = 6.460E-03 +/- 4.134E-06
Real eff = 0.9549 +/- 0.0012
---
Y: 0.9623 +/- 0.0011
Prob noise eff = 2.739E-03 +/- 3.803E-06
Real eff = 0.9622 +/- 0.0011
---
AND eff
AND: 0.9300 +/- 0.0015
Prob noise eff = 8.862E-06 +/- 1.672E-08
Real eff = 0.9300 +/- 0.0015
---
---
Planar 3
X: 0.9664 +/- 0.0011
Prob noise eff = 1.010E-02 +/- 4.225E-06
Real eff = 0.9661 +/- 0.0011
---
Y: 0.9684 +/- 0.0010
Prob noise eff = 3.941E-03 +/- 3.725E-06
Real eff = 0.9683 +/- 0.0010
---
AND eff
AND: 0.9437 +/- 0.0014
Prob noise eff = 1.995E-05 +/- 2.515E-08
Real eff = 0.9437 +/- 0.0014
---
```

## Risoluzione

```
Planar 0 view x: Sigma_0=112.07 um, Sigma_1=259.82 um, error tracking: 95.67 um
Planar 0 view y: Sigma_0=109.32 um, Sigma_1=305.45 um, error tracking: 95.92 um
Planar 1 view x: Sigma_0=70.38 um, Sigma_1=158.98 um, error tracking: 36.13 um
Planar 1 view y: Sigma_0=68.25 um, Sigma_1=191.18 um, error tracking: 33.39 um
Planar 2 view x: Sigma_0=64.14 um, Sigma_1=157.80 um, error tracking: 41.10 um
Planar 2 view y: Sigma_0=62.09 um, Sigma_1=132.52 um, error tracking: 52.63 um
Planar 3 view x: Sigma_0=98.10 um, Sigma_1=250.02 um, error tracking: 99.66 um
Planar 3 view y: Sigma_0=97.91 um, Sigma_1=232.22 um, error tracking: 128.84 um
```

--Enemy residual--

--Enemy residual x--

```
Couple: (0, 1): 0.015198357672251805 cm
Couple: (1, 2): 0.014404786859136154 cm
Couple: (2, 3): 0.014189314977784806 cm
Couple: (0, 2): 0.02165354472714759 cm
Couple: (1, 3): 0.021162411951882787 cm
Couple: (0, 3): 0.029306071005829548 cm
System solution:
(0.00920426246712921, 0.00809560402131984, 0.00782472083126620,
0.00770568488530741, 0.00898514462320344, 0.0267348044818596)
```

--Enemy residual y--

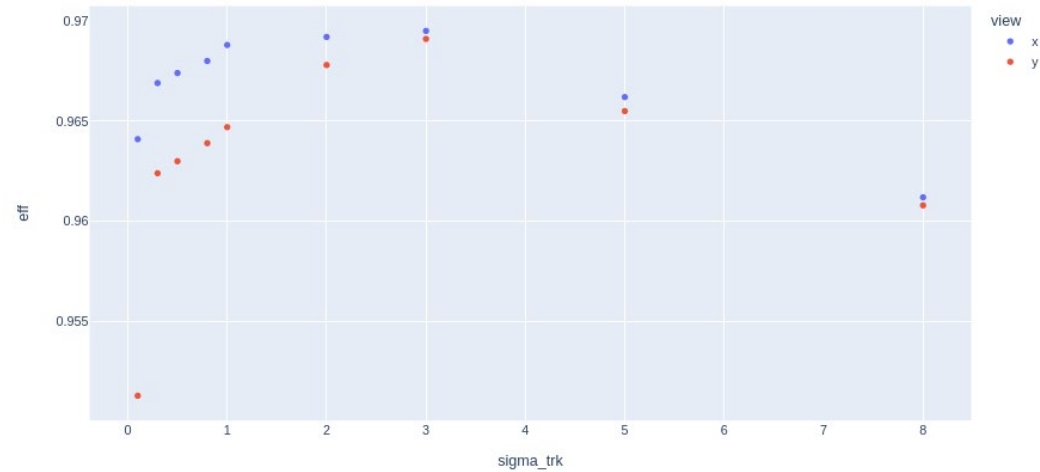
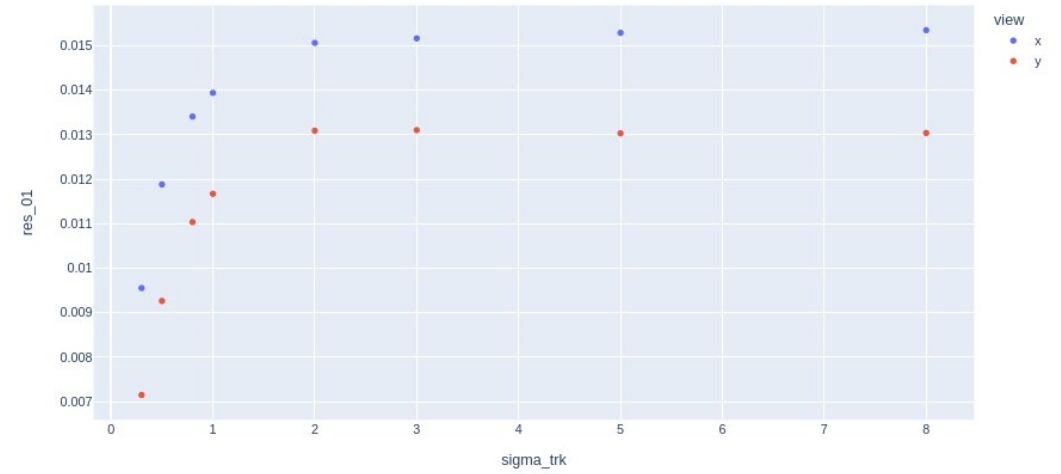
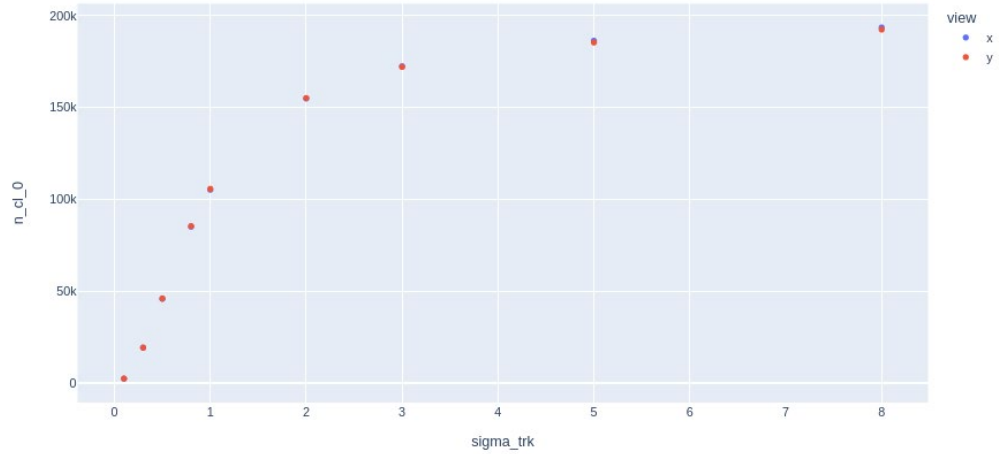
```
Couple: (0, 1): 0.015198357672251805 cm
Couple: (1, 2): 0.014404786859136154 cm
Couple: (2, 3): 0.014189314977784806 cm
Couple: (0, 2): 0.02165354472714759 cm
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System solution:
(0.00920426246712921, 0.00809560402131984, 0.00782472083126620,
0.00770568488530741, 0.00898514462320344, 0.0267348044818596)
```



# Due studi

Taglio sui tracciatori

# Taglio su $n$ sigma della distr tracciatori



# Taglio su $n \chi^2$

